LOCAL AREA NETWORKS VIA PACKET RADIO MEDIA

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Abstract

Investigations are underway by the Amateur Radio community to incorporate digital communications techniques into the Amateur Service. The network system utilizes simple techniques, using normal terminals and personal computers, and a wide variety of amateur radio transceivers. Complete local area network protocols are realized by incorporating a micro-processor based interface unit to connect the terminal device and radio. Physical-level protocol involves half-duplex transmissions with frequency-modulated transceivers. A data-link control is implemented, and two connecting protocols are being tested on top of these lower levels. The TAPR/AMSAT protocol provides multiple point-to-point connections on the channel. The TAPR/DA (dynamic-addressing) protocol implements a full datagram network, and uses a robust network control scheme to provide near-optimum channel utilization and network tolerance to a number of error conditions related to open radio channels.

Introduction

The Tucson Amateur Packet Radio group is currently coordinating a series of tests with Amateur Radio operators in eighteen major U.S. cities, to investigate the use of digital computer and terminal communications using packet radio techniques. Initial investigations are being performed on the Amateur Radio Service VHF bands, using half-duplex transmissions. Two sets of experiments are being undertaken; the first is testing multiple simultaneous connections on a single shared frequency, while the second tests a new form of efficient radio frequency local area network.

A general description of the system is given in terms of the signals and medium access. This is followed by information on the hardware implementation. A more detailed description of the signalling technique, data link protocol and the two types of link and network protocols are described.

Physical and Medium Access Protocols

Both protocol tests are using a common medium. Access to the radio channel is accomplished using audio frequency shift keying within the normal audio communications passband. The packet radios are able to detect digital communications on the channel, and will defer transmissions while there is activity on the channel. Collisions, interference and unusual conditions (fading, multipath, etc.) which cause unsuccessful transmissions will result in no acknowledgement, and an automatic retransmission will result after a set delay. Multiple unsuccessful transmissions will produce an error indication at the data source. Successful transmissions will result in an acknowledgement being transmitted to the originating station. The acknowledgements may occur after each packet, or may be deferred for up to seven packets, using standard high-level bit-oriented data link protocol (HDLC), implemented with large-scale integrated circuitry.

This multiple-access protocol is therefore based on on-channel data sensing, with negative acknowledgement causing retransmission (data-sensed multiple-access with collision-detection by negative acknowledgement, or DSMA/NAK). It should be noted that the normal LAN technique of carrier-sensing is not appropriate to the Amateur Radio Service, where all manner of signals are apt to impinge on the data channel. Use of much less occupied bands is possible, and conversion to carrier-sensing trivial. However, the choice of using the more heavily-used bands was made to provide exposure to the general population, and promote acceptance of this new mode.

Hardware

The Tucson Amateur Packet Radio Corporation (TAPR) has created a single-board packet radio terminal node controller (TNC) which interfaces standard microcomputers or data terminals to commonly available Amateur Radio transceivers.

Initial investigations in Tucson are using the two-meter band (144-148MHz), and both this band and others will be used in the other seventeen test sites. This band was chosen for maximum visibility within the Amateur community.

The transceiver interface is performed without modifications to the unit by using the three normally-available signal lines; audio input (microphone), audio out (speaker) and transmit (push-to-talk). This ease of equipment configuration was the primary reason to use audio-frequency shift

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keying, and to keep the modulating signals within the audio passband.

The digital data from the terminal or computer is fed to the packet radio interface board either through a standard RS-232 serial interface port, or by using a custom parallel interface. TTL-level lines are provided on the board for these connections, and a wire-wrap area is also included for non-standard interconnects.

The TNC accepts the serial or parallel data and formats the data into packets, using the standard HDLC format as described below. These serial packets are encoded using a non-return-to-zero inverted (NRZI) code to assist in providing an audio signal for the demodulator to lock on, using phase-locked loops. This NRZI data is presented to the audio FSK modulator, and the modulated signal is fed to the audio input of the transceiver.

The received signal appears as an AFSK signal on the audio output of the radio. A side benefit of using standard Amateur radios is the availability of a speaker for monitoring the channel while the experiments are in progress, although experience suggests that continued monitoring can be most distracting.

The signalling tones used to modulate the radio were chosen to be compatible with those of the Bell 202 half-duplex modem set of standards. This was done both to use a well-tested pair of frequencies with much operating experience, and to allow earlier experimenters with surplus 202-type modems to use their equipment, expanding the size of the test community. The main drawback to the 202-type modem is the limitation of 1200 bits/second of data transmission. Further experimentation is planned for higher-speed phase-shift keying modems within radios built expressly for packet radio service.

Hardware also exists on board to handle packet encoding and decoding, buffering, and system initialization and calibration. All components necessary to provide the channel access and data link control, as well as network protocol, are also contained on the TNC. A built-in modem and power supply minimize the complexity of installation.

Data Link Control

Both protocols being investigated use similar data-link protocols, although there are differences in addressing modes. An HDLC controller integrated circuit provides most of the circuitry for building and disassembling the packets. HDLC framing signals, address bytes, control byte and trailing cyclic redundancy check butes are employed without modification. Successful packets are acknowledged on receipt, using standard HDLC control modes. Each packet is checked for correct CRC calculation, and the acknowledgement packet is withheld if the CRC is incorrect. This forces a retransmission by the source station. Retransmitted packets are thereby forced either by incorrect CRC calculation or by having been interfered with (collisions or unwanted signals). Collisions of packets are minimized by the data-sensing capabilities of the packet radios.

The decision of the next time to retransmit a packet will be weighted by a binary-exponent random back-off algorithm, similar to that used by Ethernet-like systems. This minimizes the possibility of continuing collisions by radios with nearly-synchronous retransmission attempts.

Unlike most LAN media, the open radio channel susceptibility to intentional and unintentional interference adds complexity to the link-level algorithms used to reschedule transmissions. Another problem is the phenomenon of "capture" of the receiver demodulator by FM signals stronger than that of the desired signal.

Connection-oriented Protocol

The first protocol used to exercise the packet radio system was one developed simultaneously by groups in the Los Angeles and Washington, D.C. areas, and approved and "standardized" at a meeting sponsored by the Radio Amateur Satellite Corporation (AMSAT) in October of 1982. The implementation of this TAPR/AMSAT protocol provides a means of connecting pairs of packet radios with a communication channel transparent to other users of the shared channel. While lacking some of the capabilities of a full local area network, this protocol nevertheless provides a means of experimenting with channel capacity, access algorithms and system parameters.

The TAPR/AMSAT implementation provides the same types of functions as the link-access protocol of X.25. Connection and disconnection, error indications and control, and flow control are all provided. Virtual circuits are supported on the channel and channel-wide monitoring is available.

The addressing scheme is unique, in that the Amateur Radio Service has associated with each station a single call sign, that of the station owner/operator. The packet radios have made use of this uniqueness to provide unambiguous addressing, both within LAN's and across future internetwork gateways. A serious drawback is the requirement of seven bytes for both sending and receiving addresses, but on the half-duplex channels currently in use, this added overhead is not noticeable.

A further enhancement allows extension of the network to larger geographical areas with any of the stations acting as a store-and-forward packet repeater. Stations requiring repeat services use bits in the HDLC control word to signal the need to have a message repeated, and repeated messages turn off this bit to prevent possible multiple acknowledgements.

Although this protocol is designed primarily for point-to-point links within a larger multi-point network configuration, it does lend itself

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Amateur Radio Digital Communications, Grant 151

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well to some of the needs of the shared-channel packet system, including terminal-to-host and host-to-host connections.

Datagram Protocol with Dynamic Addressing

The second protocol being used in the packet radio experiment test beds has a more efficient addressing scheme, providing each station with a mechanism to obtain a one-byte address when first accessing the network. This dynamic-addressing protocol, called TAPR/DA, provides a full network configuration with connectionless protocol and a centralized, failure-tolerant network control mechanism.

The unique aspect of this LAN protocol is this utilization of dynamic address allocation. A network control station (NCS) monitors for stations attempting to sign on, and replaces the amateur radio call sign sent to the NCS with a single byte address for efficiency. Each station then has available from the NCS a list of users (amateur call signs) and corresponding assigned addresses. This list is the system status table. For robustness and ease of switching to other radio channels, the first station on any given frequency will automatically be chosen as the NCS, and in the event of loss of this station, the next station attempting transmissions which require the NCS will become the NCS.

This protocol also supports a store-and-forward repeat capability. The possibility of hearing stations in a different network geographically remote, but using the same frequency requires special algorithms. The conditions of multiple store-and-forward digipeaters, network control stations or identically-addressed stations must be detected and corrected.

Currently experiments are underway to further extend network topology through the use of specified stations as network-to-network links, using separate radio channels. Additionally, the use of amateur radio satellites is being planned.

Acknowledgements

The author wishes to acknowledge the efforts of Lyle Johnson, who is the principal architect of the terminal node controller hardware. Margaret Morrison, Harold Price and David Henderson wrote the TAPR/AMSAT software for the system, and Marcus Chamberlin and David McClain produced the TAPR/DA software. Design credit also goes to all of the above, as well as Charles Green, Mark Baker and Dan Morrison for several design concepts. Further gratitude is given to the 180 hams who have volunteered a wide variety of resources to help test the system.